

UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
THE RADIATION LABORATORY
DEPARTMENT OF ELECTRICAL ENGINEERING
AND COMPUTER SCIENCE

3242 EECS BUILDING
1301 BEAL AVENUE
ANN ARBOR MICHIGAN 48109-2122
734 936-2597, FAX 734 647-2106
<http://www.eecs.umich.edu/RADLAB/>

CONSIDERED: /B.T.L./

July 20, 2010

United States Patent and Trademark Office

To Whom It May Concern:

I Amir Mortazawi hereby declare that the extended resonance phased array presented in our invention is significantly different from Kirino and Mantele patents in its design, implementation and function.

The extended resonance array combines the phase shifting and power dividing functions in a phased array into a single circuit. The extended resonance circuit achieves phase shifting unlike the distributed phase shifter described in Mantele's patent. Mantele's distributed phase shifter for each stage (as stated in the title of the patent, and in many other places such as Column 3, line 38-53) approximates a section of a transmission line. In the overview of his invention, Mantele uses the general formulation of distributed transmission lines to describe his variable delay phase shifter. In order to achieve the required phase shift, Mantele's design, due to its distributed nature, requires many transmission line sections and varactors to be connected in tandem for each stage. For example Mantele uses 14 varactor diodes just for a single stage of phase shifter (Column 6, line 25). The phase shift values that he has achieved are in the order of 10 degrees. This value of phase shift is quite insufficient for designing a practical phased array with a reasonable scan angle. As Mantele puts it (column 6, line 60), thousand of varactors are needed for the design of a phased array based on his approach.

In contrast, the extended resonance design phase shifting at each stage is achieved with using only a single tunable admittance in shunt (tunable capacitor) and a series tunable impedance (tunable inductor) in series as indicated in Fig. 2 of our patent application. The extended resonance design does not behave like a distributed phase shifter. A distributed phase shifter provides phase shift by changing the speed of wave propagation through an artificial transmission line (loaded line), hence achieving a variable delay. In extended resonance design, the phase of the AC current through the series lumped element impedance varies as a function of the values of the tunable lumped elements (tunable capacitor and inductor). By using the extended resonance design procedure we can achieve phase shifts that are larger than 100 degrees through employing only two tunable lumped elements at each stage. The entire phased arrays that we have demonstrated (which can include many stages) require only few varactors (less than the number of varactors required in a single stage of the Mantele's patent).

Furthermore as it is mentioned in Mantele's patent [Claim 3, line 25-35], [column 11, line 6-11], [column 13, line 5-10], as the varactors in his distributed phase shifter are tuned to achieve

various phase shifts, the characteristic impedance of the distributed phase shifter varies, causing an impedance mismatch to load and source. This causes an increased insertion loss due to the impedance mismatch and reflections across the Mantele's phase shifter. In his own word Mantele says: "Since the characteristic impedance of the line also changes with changes in the varactor capacitance, the magnitude of the capacitance change must be limited; otherwise a significant mismatch would occur between the phase shifter transmission line and connecting transmission line, which would result in increasing the insertion loss of the phase shifter".

Because of the above issue, Mantele's phase shifter cannot be combined with Kirino's design because Kirino suggests non-tunable matching circuits for antenna matching. Therefore, Kirino's design will not be able to correct for (adapt to) the characteristic impedance variation of the distributed phase shifter described by Mantele. Consequently, if Mantele's distributed phase shifter is used in Krino's array, because of its characteristic impedance variation, an equal power distribution across the Kirino's array cannot be provided. In other words, each antenna element in Kirino's design will receive a different amount of power. In a serially fed array such as the one described in Krino's patent, any impedance mismatch at each stage is cumulatively transferred down the feed line resulting in a large impedance mismatch at the input to the entire serially fed array. Therefore Matele's phase shifter would not be an appropriate phase shifter for the design of Krino's phased arrays.

On the contrary, we have devised a circuit topology that employs a tunable shunt admittance and a tunable series impedance at each stage to achieve a significant phase shift as opposed to Mantele's design which requires many varactors in each stage due to its distributed nature. At the same time, the extended resonance design, allows for equal power distribution across the array. In other words, the extended resonance circuit behaves like a power divider and phase shifter concurrently. The impedance match to each antenna element across the array is maintained while varactors are tuned therefore there is no need to use a matching circuit at each stage to achieve equal power division. We have designed an elegant and compact single circuit that functions as both as an equal power divider and phase shifter.

Our design strategy allows for equal power distribution to each antenna node while the varactors are tuned to achieve a variable phase shift between the adjacent antenna elements. By conjugating the admittances across the array, we effectively place the antennas in shunt with each other (although there is a phase difference between the voltages and the currents at each antenna node) hence our circuit achieves an equal power division among the antennas. The specific design procedure described in our patent application allows for the admittance conjugation across the array to be maintained while the phase shift across each stage is varied as varactors are tuned thereby satisfying equal power division across antennas. Our design achieves a variable phase shift while maintaining equal power division among the antennas.

Other significant differences between our design and Kirino/Mantele's design include:

- a) The extended resonance provides the phase shifting and the power division simultaneously without any need for separate matching networks at each antenna node. This avoids the addition of matching networks which not only complicate the array design but also add to its loss.

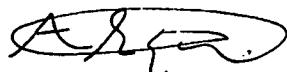
b) Kirino's phased array does not allow the designer to use the same antenna and a fixed (non tunable) matching network at each stage to design the entire array. At least one of these elements (either the antennas or the matching networks) should be designed separately for each section of the phased array. This will significantly complicate the design process. On the contrary, the extended resonance network can use the same antenna design without any extra matching networks to achieve equal power distribution and phase shifting across the array.

At one point the patent examiner has concluded that: "it would be obvious for one skilled in the art to select a conjugate admittance as a desirable impedance characteristic especially since the conjugate admittance would necessarily compensate for the imaginary component of the impedance".

I believe that the examiner is confusing the extended resonance design described in our patent application with the conventional conjugate impedance/admittance matching procedure. In conventional impedance/admittance matching, the load impedance or admittance is converted to the conjugate of the source impedance/admittance. The extended resonance design process is significantly different. Here we transform the impedance/admittance of the antenna and varactors combination to a conjugate of itself; not to a conjugate of the source impedance/admittance. This is immaterial of the source impedance/admittance value (the impedance seen by looking into the left of the circuit). This process is repeated at every stage of the extended resonance array design. Impedances/admittances looking into the left and right are not conjugates of each other as is in the case of standard conjugate matching. In our patent application, we do not mention anything about compensating for the impedance or admittance values!

This Declaration is submitted in a response to a non-final rejection. I further state that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true and that all statements were made with the knowledge that willful, false statements or the like so made are punishable by fine, imprisonment, or both under Section 1001 of the United States Cod and that such false statements may jeopardize the validity of the patent.

With Regards,



Amir Mortazawi
Professor
EECS Department
University of Michigan